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Amounts of Artificial Food Dyes and Added Sugars in Foods and Sweets Commonly Consumed by Children

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Abstract

Artificial food colors (AFCs) are used to color many beverages, foods, and sweets in the United States and throughout the world. In the United States, the Food and Drug Administration (FDA) limits the AFCs allowed in the diet to 9 different colors. The FDA certifies each batch of manufactured AFCs to guarantee purity and safety. The amount certified has risen from 12 mg/capita/d in 1950 to 62 mg/capita/d in 2010. Previously, we reported the amounts of AFCs in commonly consumed beverages. In this article, the amounts of AFCs in commonly consumed foods and sweets are reported. In addition, the amount of sugars in each product is included. Amounts of AFCs reported here along with the beverage data show that many children could be consuming far more dyes than previously thought. Clinical guidance is given to help caregivers avoid AFCs and reduce the amount of sugars in children's diets.

Keywords

Allura Red, artificial food colors, attention-deficit hyperactivity disorder (ADHD), candy, childhood behavioral problems, high-fructose corn syrup, hyperactivity, sugars, tartrazine

Introduction

Artificial food colors (AFCs) are widely used to dye beverages, foods, and sweets worldwide. In the United States, 9 different AFCs are approved for use in foods by the Food and Drug Administration (FDA). Of these, 4 are widely used (FD&C Red #40 [Allura Red], Yellow #5 [Tartrazine], Yellow #6 [Sunset Yellow], and Blue #1 [Brilliant Blue]), whereas 3 (FD&C Blue #2, Green #3, and Red #3) are rarely used. Two are no longer used (Citrus Red #2 and Orange B). Some of these AFCs, known as Lakes, may be bound to aluminum or another substrate to color some foods. For example, Yellow #5 is dissolved in many beverages and foods to color them a bright yellow, whereas Lake Yellow #5 appears in some foods such as icings and candies and tints by dispersion. The total amount of per capita AFCs certified by the FDA has increased 5-fold from 1950 (12 mg/capita/d) to 2012 (62 mg/capita/d). For more information about the 35 years of research investigating the role of AFCs in children's behavior (hyperactivity, attention-deficit hyperactivity disorder [ADHD]), possible mechanisms of how AFCs produce reactions, and amounts of AFCs in beverages see Stevens and colleagues,[1-3] Nigg et al,[4] and Arnold et al.[5]

One of the largest sources of AFCs in the American diet is beverages.[1] This is not because beverages are colored more vividly but, rather, because of the large volume of fluid that is consumed in a serving. AFCs are also found in some ready-to-eat (RTE) cereals, popsicles, ice cream and sherbets, gelatin, puddings, cakes, cookies, boxed dinners, beverage syrups, snacks, and candy. The amounts of AFCs in common foods and sweets are reported in Tables 1 to 6. Amounts of added sugars are also included because high sugar levels are frequently found in foods containing AFCs.

Materials and Methods

Foods and candies listing AFCs on their labels were purchased from local grocery stores, superstores, pharmacies, movie theaters, ice cream stores, amusement parks, and convenience stores. Powdered colors were obtained

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Table 1. Amounts of Artificial Food Colors (AFCs, in mg) and Sugars (g) in 1 Serving of Commonly Consumed Breakfast Foods.

Food	1 Serving[a]	Weight Per Serving	Colors Added[b]	Lake AFCs	AFC (mg) Per Serving	Sugars (g) Per Serving
Breakfast cereals						
Special K Red Berries	1 c	31 g	Strawberries		0	9
Berry Berry Kix	1¼ c	33 g	Fruit juice		0	7
Fruit Loops	1 Small box	27 g	R40, B2, Y6, B1, annatto, turmeric[c]		14.6	12
Apple Jacks	1 Small box	27 g	R40, Y6, B1		9.4	12
Trix	1 c	32 g	Y6, B1, R40		36.4	10
Fruity Cheerios	¾ c	27 g	R40, Y6, B1		31.8	9
Fruity Pebbles	¾ c	27 g	R40, Y5, B1, B2		19.0	9
Cap'n Crunch	¾ c	27 g	Y5, Y6		9.5	12
Cap'n Crunch's Crunch Berries	¾ c	26 g	Y5, R40, Y6, B1		17.0	11
Cap'n Crunch's Oops All Berries	1 c	32 g	R40, Y5, B1		41.3	15
Cereal bars and poptarts						
Quaker Chewy Yogurt Granola Bars	1 Bar	35 g	Strawberries, "artificial color"		0	11
Nature Valley Crunchy Oats 'n Honey Granola Bars	2 Bars	42 g	None		0	12
Kellogg Frosted Cherry Poptart	1 Pastry	52 g	R40, Y6, B1 caramel, cherries	R40	10.1[c]	17
Kellogg Frosted Blueberry Poptart	1 Pastry	52 g	R40, B2, B1, turmeric, blueberries		9.6[c]	16
Kellogg's Strawberry NutriGrain	1 Bar	37 g	R40, caramel, strawberries		2.5[c]	16
Special K Pastry Crisp	2 Crisps	25 g	R40, strawberries, caramel		10.3[c]	7

[a]c, Cup; T, tablespoons.
[b]FD&C artificial colors: B1, Blue #1; B2, Blue #2; G3, Green #3; Y5, Yellow #5; Y6, Yellow #6; R3, Red #3; R40, Red #40.
[c]Amounts of AFCs in foods containing natural dyes and foods may be elevated.

from Sensient Colors LLC (St Louis, MO) and were used as standards. The standards were made up in water or 5% acetic acid. The 5% acetic acid solution was used for products containing lakes to release dyes from the aluminum substrate.

Serving size was chosen from the manufacturer's Nutrition Facts food label, but within some groups of foods and candies, serving sizes varied. For example, some cereals listed three-fourths of a cup of cereal as a serving size, whereas others used 1 cup. Serving size for popsicles and candies also varied. Two different methods were used to process multicolored foods and candies. (1) For example, for colored cereals, the number of each color in a serving was determined in 3 samples, averaged, and a percentage of each serving was calculated. Colors were measured individually, the amounts of each color in a serving were calculated, and the results added together. (2) Three samples of the cereal were weighed, crushed, and mixed together. Three samples of the mix were processed, and the total amounts of AFCs in the 3 samples were averaged. Both methods produced comparable results. For gelatin desserts, puddings, and cake mixes, a sample of each powder was weighed, dissolved in water, and analyzed. The result was calculated for the sample, then calculated for the serving.

Sample preparation depended on the food being analyzed. Slushies and popsicles were allowed to melt, then diluted with water if the color was intense. If they did not contain any fats or oils, cereals and other foods were dissolved in water or 5% acetic acid, vortexed, and centrifuged. If the top layer was cloudy, the sample was filtered using an Ester filter or Whatman #5 filter. Foods and candies containing fats or oils were dissolved first in water (or 5% acetic acid if lakes were present), then vortexed. Ethanol was added and the sample vortexed. Hexane was added to each sample, vortexed, then centrifuged at 4000 rpm for 10 minutes. The aqueous layer with the colors was removed and then filtered if cloudy. Following sample preparation, 200 µL of sample was loaded in triplicate onto a FALCON (Franklin Lakes,

Table 2. Amounts of Artificial Food Colors (AFCs, in mg) and Sugars (g) in 1 Serving of Frozen Foods.

Food	1 Serving[a]	Weight or Volume/ serving	Colors Added[b]	Lake AFCs	AFC (mg) Per Serving	Sugars (g) Per Serving
Popsicles						
Edy's Outshine Lime	1 Pop	86 g	Lime peel		0	17
Edy's Outshine	1 Pop	86 g	Beet juice, turmeric		0	17
Strawberry						
Edy's Outshine Grape	1 Pop	86 g	Grape juice		0	16
Dole Fruit Juice Bars	1 Pop	52 mL	Fruit juice		0	6
Fla-vor-ice	1 Pop	43 mL				
Red			R40		3.8	5
Orange			Y6		0.5	5
Green			B1, Y5		1.9	5
Blue			B1		1.0	5
Grape			B1, R40		1.2	5
Popsicles	1 Pop	45 mL				
Orange			Fruit juice		0.0	8
Cherry			R40		9.9	8
Grape			Fruit juice		0.0	8
Rainbow pops	1 Pop	50 mL				
Orange			Y6, R40		13.4	10
Lime			B1, Y5		5.0	10
Grape			B1, R40		7.2	8
Red			R40		5.0	8
Freezer pops	1 Pop	64 mL				
Orange			Y5, Y6, R40		10.7	11
Purple			B1, R40		4.4	11
Blue			B1		0.6	11
Red			R40		4.0	11
Yellow			Y5		3.5	11
Green			G3		0.3	11
Tampico Freezer Pops	1 pop	72mL				
Tropical Punch			R40		3.2	8
Citrus Punch			Y6		3.5	8
Mango Punch			Y6		3.3	8
Kiwi Strawberry			Y5, B1		1.9	8
Blue Raspberry			B1		0.4	8
Slushies						
Red	1 Small	325 mL	R40, B1		22.4	43[c]
Orange	1 Small	295 mL	Y6		11.1	43[c]
Green	1 Small	300 mL	Y5, B1		4.3	43[c]
Blue	1 small	325 mL	B1		1.6	43[c]

[a]c, Cup; T, tablespoons; pop, popsicle.
[b]FD&C artificial colors: B1, Blue #1; B2, Blue #2; G3, Green #3; Y5, Yellow #5; Y6, Yellow #6; R3, Red #3; R40, Red #40.
[c]Estimated from database.

NJ) 96-well flat bottom assay plate, catalog number 353228.

Spectrophotometric analysis was done using a Power Wave X spectrophotometer (Bio Tek Instruments, Winooski, VT). Wavelengths used were 500 nm for Red #40, 525 nm for Red #3, 425 nm for Yellow #5, 480 nm for Yellow #6, 630 nm for Blue #1, 610 nm for Blue #2, and 625 nm for Green #3. For samples containing lakes, 5% acetic acid was used as a blank; otherwise water was used. Blank absorbance values were subtracted from the sample absorbances accordingly. Results from the spectrophotometer (in mg/mL) were adjusted, so that the result was the amount in the sample. The amount was then calculated to be the amount in 1 serving.

Table 3. Amounts of Artificial Food Colors (AFCs, in mg) and Sugars (g) in 1 Serving of Dairy Foods.

Food	1 Serving[a]	Weight or Volume/ Serving	Colors Added[b]	Lake AFCs	AFC (mg) Per Serving	Sugars (g) Per Serving
Strawberry milk						
Nesquik Strawberry	1 c	240 mL	R3		2.5	30[c]
Shamrock Farms Strawberry	1 c	240 mL	R40		4.0	42[c]
Sherbets						
Food Club Lime	½ c	86 g	B1, Y5		2.7	26
Food Club Orange	½ c	86 g	Y6		5.2	17
Food Club Raspberry	½ c	86 g	B1, R40		3.5	26
Ice creams						
Breyers No Sugar Added Vanilla	½ c	60 g	Annatto		0	4
Breyers French Vanilla	½ c	65 g	Egg yolk		0	14
Breyers Cherry Vanilla Ice cream	½ c	65 g	Cherries		0	16
Edy's Slow Churned Yogurt Blends	½ c	59	Annatto		0	13
Edy's Slow Churned Vanilla	½ c	65 g	Annatto		0	0
Coldstone Creamery Blue Ice Cream—Cotton Candy	1 Scoop	200 mL	B1		1.9	14[d]
Coldstone Creamery Green Ice Cream—Mint	1 Scoop	200 mL	Y5, G3		6.0	14[d]
Puddings						
Jello Lemon	½ c	25 g	Y5, Y6		5.2	19
Jello Vanilla	½ c	25 g	Y5, Y6		2.5	19
Jello Banana Cream	½ c	25 g	Y5, Y6		5.0	18
Hunt's Snack Pack Lemon Pudding	1 Container	99 g	Y5		2.2	18
Yogurts						
Yoplait Original Strawberry	1 Container	170 g	Beet juice		0	26
Yoplait Strawberry Banana Bash	1 Container	170 g	Vegetable juice, β-carotene, turmeric		0	14
Yoplait French Vanilla	1 Container	170 g	Turmeric annatto		0	27
Yoplait Strawberry Kiwi	1 Container	113 g	B1, Y5, R40		4.5	26
Yoplait Bubblegum	1 Container	113 g	R40, B1		1.4	19
Dannon Raspberry Light & Fit	1 Container	170 g	R40, B1		5.1	10

[a]c, Cup; T, tablespoons.
[b]FD&C artificial colors: B1, Blue #1; B2, Blue #2; G3, Green #3; Y5, Yellow #5; Y6, Yellow #6; R3, Red #3; R40, Red #40.
[c]Natural sugars in white milk are 12.6 g in 240 mL.
[d]Estimated from database.

Results

The results from the spectrophotometric analyses of foods and candy giving the amounts of AFCs in 1 serving of foods or candies are found in Tables 1 to 6. The amount of sugars in a serving is also reported in these tables based on the Nutrition Facts label on each product (4 g is roughly 1 teaspoon). The amounts of AFCs in the 8 cereals analyzed ranged from 9.4 to 41.3 mg per serving, whereas the sugars ranged from 9 to 15 g per serving. The AFCs in 5 brands of popsicles ranged from 0.3 mg to 13.4 mg/popsicle with 5 to 11 g of sugars. Small slushies contained from 1.6 to 22.4 mg of AFCs. (The sources of the slushies and 2 ice cream samples did not reveal the amounts of sugars in their products, so these amounts were estimated based on similar foods.) AFCs in 3 sherbets and 2 grocery store ice creams ranged from 1.9 mg to 6.0 mg per serving and contained 14 to 26 g sugars. Puddings and yogurts contained from 1.4 mg to 5.2 mg per serving of AFCs and 14 to 26 g of sugars. Cakes (no icing), iced cupcakes, and iced minicupcakes contained from 2.2 to 55.3 mg per serving of AFCs and 17 to 35 g of sugar. AFCs in cupcake icings ranged from 1.2 to 34.7 mg per 2 tablespoons and contained 19 g of sugars. AFCs in candies ranged from 0.2 to 33.3 mg per serving and contained 7 to 46 g of sugar per serving.

The most commonly used AFC was Red #40 (82 foods and candies), with Yellow #5 (69 foods/candies)

Table 4. Amounts of Artificial Food Colors (AFCs, in mg) and Sugars (g) in 1 Serving of Baked Goods and Desserts.

Food	1 Serving[a]	Weight or Volume Per Serving	Colors Added[b]	Lake AFCs	AFC (mg) Per Serving	Sugars (g) Per Serving
Cookies						
Pepperidge Farm Chessman	3	26 g	None		0	5
Pepperidge Farm Bordeau	4	27 g	None		0	12
Keebler Simply Made	2	27 g	None		0	6
Blue cookie	1	33 g	B1, Y5, R40		1.2	4[c]
Marsh Red Sprinkles Cookie	1	35 g	R3, Y6, R40, B2		6.1	12
Marsh Green Sprinkles Cookie	1	35 g	Y5, B1, Y6	Y5,B1	1.4	12
Strawberry Wafers	3	25 g	R40		24.2	12
Cakes						
Hostess Orange Cupcake	1 Cupcake	53 g	Y5, Y6, R40, caramel	Y5, Y6	3.5	25
Pillsbury Classic Moist Supreme Yellow Cake Mix	1/12 Cake	43-g Mix	Y5, R40		2.2	18
Duncan Hines Red Velvet Cake	1/12 Cake	39-g Mix	R40		9.5	17
Target Mini Green Cupcakes	3 Cupcakes	75 g	Y5, B1, Y6, R40		55.3	35
Duff Blue Suede Cake	1/12 Cake		B1, B2, R3, R40		12.4	19
Icings						
Betty Crocker's Blue Cupcake	2 T	35 g	B1	B1	1.2	19
Betty Crocker's Yellow Cupcake	2 T	35 g	Y5		8.6	19
Betty Crocker's Red Cupcake	2 T	35 g	R40, R3	R40	34.7	19
Betty Crocker's Green Cupcake	2 T	35 g	Y5, B1		18.3	19
Donuts						
Marsh Supermarket Red	One 3½″	77 g	R40		19.5	24[c]
Marsh Supermarket Green	One 3½″	97 g	Y5, Y6, B1		17.4	24[c]
Gelatin						
Jell-o Berry Blue	½ c	120 mL	B1		1.0	19
Jell-o Orange	½ c	120 mL	Y6, R40		12.2	19
Jell-o Lime	½ c	120 mL	B1, Y5		2.2	19
Jell-o Strawberry	½ c	120 mL	R40		6.9	19
Jell-o Lemon	½ c	120 mL	Y5, Y6		3.4	19
Jell-o Black Cherry	½ c	120 mL	R40, B1		9.0	19
Jell-o Black Cherry SF	½ c	120 mL	R40, B1		5.6	0
Syrups and toppings						
Smucker's Marshmallow Topping	2 T	40 g		B2	Trace	24
Smucker's Caramel	2 T	41 g	Y5, Y6		2.7	24
Smucker's Butterscotch	2 T	41 g	Y5, Y6		3.6	24
Hershey's Strawberry	2 T	40 g	R40		0.6	24

Abbreviation: SF, sugar free.
[a]c, cup; T, tablespoons.
[b]FD&C artificial colors: B1, Blue #1; B2, Blue #2; G3, Green #3; Y5, Yellow #5; Y6, Yellow #6; R3, Red #3; R40, Red #40.
[c]Estimated from database.

and Yellow #6 (62 foods/candies) next. This is not surprising because the FDA each year certifies more Red #40 than the other dyes, followed by Yellow #5 and Yellow #6. Blue #1 was commonly used to dye blue-, green-, and purple-colored foods. The use of Blue #2 (12 products) was much rarer because the dye quickly fades in solution and on exposure to light. Red #3 was found in 8 products and Green #3 in just 2. Red #40 and one or both of the yellow dyes were used to impart an orange color. Some products were dyed with both Yellow #5 and Yellow #6. Because the wavelengths of these 2 dyes overlap, only 1 color was selected (the larger concentration of the 2) to calculate the total AFCs. This was also true for Blue #1 and Blue #2 and for Red #3 and Red #40.

Table 5. Amounts of Artificial Food Colors (AFCs, in mg) and Sugars (g) in 1 Serving of Miscellaneous Foods and Artificial Food Dyes.

Food	1 Serving[a]	Weight Per Serving	Color Sources[b]	Lake AFCs	AFC (mg) Per Serving	Sugars (g) Per Serving
Snack foods						
Ritz Bits with Cheese	1 Small pack	28 g	Y6		2.8	4
Keebler Cheese &Peanut Butter Crackers	8 Crackers	51 g	Y6		14.4	4
Cheese Balls	1½ c	28 g	Y6, Y5		8.8	
Tostitos Cheese Sauce	2 T	34 g	Y5		4.6	<1
Okedoke Cheesy Popcorn	1 c	28 g	Y6, B1, R40	R40	3.8	<1
Combos	⅓ c	28 g		Y5, Y6, B1	3.2	4
Salad dressings						
Kraft Catalina	2 T	33 g	R40		4.8	9
Kraft Creamy French	2 T	31 g	Y6, Y5		5.0	6
Other foods						
Hamburger Helper	1 c Prepared	7.7 G Mix	Y5, Y6	Y5, Y6	7.7	<1
Scalloped Potatoes	½ c Prepared	12.1 g Mix		Y5, Y6	1.4	2
Kraft Macaroni & Cheese	1 c Prepared	12.1 g Mix	Y6, Y5		17.6	6
Artificial food dyes						
McCormick's Yellow	1 Drop	40 mg	Y5		2.1	0
McCormick's Red	1 Drop	40 mg	R40, R3		1.0	0
McCormick's Blue	1 Drop	40 mg	R40, B1		1.0	0
McCormick's Green	1 Drop	40 mg	Y5, B1		1.0	0

[a]c, cup; T, tablespoons.
[b]FD&C artificial colors: B1, Blue #1; B2, Blue #2; G3, Green #3; Y5, Yellow #5; Y6, Yellow #6; R3, Red #3; R40, Red #40.

Some of the products listed in Tables 1, 4, and 6 contain both natural dyes and AFCs. Natural dyes have maximum absorbance wavelengths, similar to some AFCs. For example, the maximum absorption (λ_{max}) for annatto is 482 nm and 480 nm for Yellow #6; it is 420 nm for turmeric, 425 nm for Yellow #5, 525 to 535 nm for beet powder, 500 nm for Red #40, and 525 nm for Red #3. Therefore, the estimated amounts of AFCs for those foods containing natural dyes reported in the tables are higher than if the AFC were isolated and measured without the natural dyes. Such separation was not possible for this study.

Discussion

The concentrations of AFCs per serving in Tables 1 to 6 are similar to what was reported several decades ago by the Certified Color Industry (CCI).[6] Table 7 shows that CCI analyses in 1968 and the concentrations presented in this article are comparable in most categories—beverages, dessert powders, ice creams and sherbets, and snacks. However, the CCI reported lower amounts for cereals and candies than those in Tables 1 and 6.

RTE Cereals and Breakfast Bars

AFC amounts reported in Table 1 may be higher because some of the cereals containing large amounts of dyes arrived at the marketplace after 1968 when the CCI published their report. For example, Trix was introduced in 1955 by General Mills but was given a brighter, more colorful look in 1995. Cap'n Crunch's Oops All Berries was not introduced until 1997. Fruity Cheerios was brought to market in 2006. High sugars and AFCs were frequently found together in many RTE cereals. Castetbon et al[7] studied the nutrient quality of 249 cereals and rated them as very poor (n = 46), poor (n = 69), fair (n = 89), and good (n = 45) based on added sugars, sodium, and fiber. The sugar contents varied from a high of 44.4 g/100 g cereals to a low of 1.5 g/100 g in the 249 cereals. Colored cereals containing AFCs reported in Table 1 contain 33 to 46.9 g of sugar if computed for 100 g and could be classified as very poor or poor by Castetbon's standards. Some cereal bars like Pop Tarts and Lucky Charms Treat contain AFCs, whereas others do not. For example, Kashi Peanut Butter Granola Bars do not contain AFCs and have 5 g of sugars. Quaker Chewy Yogurt Granola Bars contain "artificial color"

Table 6. Amounts of Artificial Food Colors (AFCs) and Sugars in Commonly Consumed Candies.

Candy	1 Serving[a]	Weight Per Serving	Color Sources[b]	Lake AFCs	AFC Per Serving	Sugars (g) Per Serving
Candy coated						
M & M's Milk chocolate	/¼ c = 48 Pieces	42 g	B1, B2, Y5, Y6, R40	B1, B2, Y5, Y6, R40	29.5	27
M & M's Peanuts	/¼ c = 15 Pieces	42 g	B1, B2, Y5, Y6, R40	B1, B2, Y5, Y6, R40	14.1	22
Skittles Original	1 Packet = 61 pieces	61.5 g	B1, B2, Y5, Y6, R40	B1, B2, Y5, Y6, R40	33.3	46
Reese's Pieces	51 Pieces	40 g		Y5, R40, Y6, B1	6.6	21
Hard candies						
Starlight Mints	3 Pieces	15 g	R40		1.2	10
Lifesavers						
Red	4 Pieces	15 g	R40		3.5	12
Raspberry	4 Pieces	15 g	R40, B1		1.1	12
Orange	4 Pieces	15 g	R40, Y5		1.3	12
Green	4 Pieces	14 g	Y5, B1		0.5	12
Rainbow Nerds	1 T	15 g		B1, B2, Y5, Y6, R40	3.7	14
Red Hots	20 Pieces	17 g	R40		0.3	14
Sprees	8 Pieces	15 g	Y5, Y6	B2, R40, Y5	1.9	13
Dum Dums						
Red	3 Pops	15 g	R40		1.1	11
Orange	3 Pops	15 g	R40, Y5, Y6		1.0	11
Yellow	3 Pops	15 g	Y5, Y6		0.3	11
Blue	3 Pops	15 g	B1		0.7	11
Blow Pops						
Green	1 Pop	18 g	Y5, B1, turmeric[c]		0.3	13
Cherry	1 Pop	18 g	R40		2.0	13
Strawberry	1 Pop	18 g	R40, B1,		0.4	13
Jolly Ranchers						
Watermelon	3 Pieces	18 g	R40		0.4	11
Green apple	3 Pieces	18 g	Y6, B1		0.8	11
Cherry	3 Pieces	18 g	R40		3.7	11
Grape	3 Pieces	18 g	B1, R40		2.2	11
Jawbreakers						16
Red	3 Pieces	18 g		R40	1.2	16
Orange	3 Pieces	18 g	Y6	R40, Y6, Y5	0.4	16
Purple	3 Pieces	18 g		R40, B1, B2	0.7	16
Green	3 Pieces	18 g	Y6	Y5, B1, Y6, B2	0.5	16
Yellow	3 Pieces	18 g	Y6	Y5, Y6	0.2	16
Air Heads						
Red	1 Piece	11.9 g	R40		1.8	13
Blue	1 Piece	11.9 g	B1		0.5	13
Green	1 Piece	11.9 g	Y5,B1		0.9	13
Purple	1 Piece	11.9 g	R40,B1		1.2	13
Taffy, chewy, gummy candies						
Simply Fruit Rolls Strawberry	1 Roll	14 g	Vegetable, fruit juices		0	14
Ocean Spray Fruit Flavored Snacks	1 Pouch	23 g	Real fruits		0	10
Mott's Medley	1 Pouch	23 g	Real fruits		0	10
Welch's Fruit Snacks Berries 'N Cherries	13 Pieces	26 g	R40, B1		3.5	11
Gummy Bears	15 Pieces	39 g	R40, Y5, B1		4.2	18

(continued)

Table 6. (continued)

Candy	1 Serving[a]	Weight Per Serving	Color Sources[b]	Lake AFCs	AFC Per Serving	Sugars (g) Per Serving
Life Savers Gummies	10 Pieces	40 g	R40, Y5, Y6, B1		13.2	26
Sathers Gummi Worms	4 Pieces	41 g	R40, Y5, Y6, B1		3.1	26
Dinosaurs	8 Pieces	23 g	B1, R40, Y5, Y6		6.9	14
Haribo Gold Bears	18 Pieces	40 g	Y5, B1, R40		2.6	21
Great Value Fruit Slices						
Green	3 Pieces	45 g	Y5, Y6, B1		0.7	24
Yellow	3 Pieces	45 g	Y5, Y6		4.6	24
Orange	3 Pieces	45 g	Y6, Y5		6.6	24
Red	3 Pieces	45 g	R40		6.2	24
Farley Orange Slice	3 Pieces	46 g	B1, Y5		2.0	28
Dots	11 Pieces	40 g	R40, Y5, B1		10.0	21
Chuckles	5 Pieces	56 g	B1, Y5, Y6, R40		14.9	34
Jujyfruits	15	40 g	R40, Y6, B1, Y5		7.8	22
Laffy Taffy	4 Bars	39 g	B1, Y5, R40		3.9	19
Fruit by the Foot	36″	21 g	Y5, R40, B1		8.3	9
Strawberry Twizzlers	4 Sticks	45 g	R40		13.1	19
Rainbow Twizzlers						
Red	3 Sticks	35 g	R40		11.2	15
Orange	3 Sticks	35 g	Y5, Y6, R40, R3		10	15
Yellow	3 Sticks	35 g	Y5, Y6		6.7	15
Blue	3 Sticks	35 g	B1		5.1	15
Purple	3 Sticks	35 g	R40, B1		7.2	15
Green	3 Sticks	35 g	Y5, Y6, B1		8.8	15
Fruit Gushers	1 Pouch	25 g	R40, B1, Y5, Y6		3.7	12
Fruit Roll-Ups						
Red-yellow	1 Roll	14 g	R40, Y5, Y6		3.0	7
Green-blue	1 Roll	14 g	Y5, Y6 B1		1.9	7
Starburst	8 Pieces	40 g	R40, Y5, Y6, B1		4.8	22
Tootsie Fruit Rolls	6 Pieces	40 g	B1, Y5, R40		22.1	20
Spice Drops	10 Pieces	40 g	R40, Y5, Y6, B1		4.5	23
Mike & Ike Original Fruits	23 Pieces	40 g	R40, Y5, Y6, B1		18.0	26
Sour Patch Kids	16 Pieces	40g	Y6, R40, Y5, B1		7.5	26
Holiday candies						
Candy Corn	24 Pieces	41 g	Y5, Y6, R3		4.2	34
Peeps	4 Pieces	32 g	Y5		1.2	26
Jelly Beans	14 Pieces	41 g	R40, B1, Y5, Y6, R3		5.6	30

[a]c, Cup; T, tablespoons; pops, lollypop.
[b]FD&C Artificial Colors: B1, Blue #1; B2, Blue #2; G3, Green #3; Y5, Yellow #5; Y6, Yellow #6; R3, Red #3; R40, Red #40.
[c]Amounts of AFCs in foods containing natural dyes and foods may be elevated.

and the yogurt in the bars is "yogurt flavored powder." The amount of sugar ranges from 7 to 17 g in the colored bars.

Candy and Confections

O'Neil et al[8] reported in 2011 that 32% of children aged 2 to 13 years and 30% of adolescents aged 14 to 18 years consumed candy on any given day in the United States. For candy consumers, the amount of candy eaten in a day was 35.2 g for the younger children, whereas adolescents consumed 46.2 g. Candy and sweets reported by the CCI contained lower amounts of AFCs than the candies reported here. However, their serving size was 15 g, whereas that for the selected products in this report ranged from 11.9 to 61.5 g per serving. Many chocolate candies and candy bars do not contain AFCs (some children may be sensitive to chocolate itself, causing changes in their behavior[9,10]). However, candy-coated milk chocolate M&Ms are ranked number 1 in candy

Table 7. A Comparison of Amounts of AFCs in Common Foods, Beverages, and Candies From the Certified Color Industry[a] and the Results in Tables 1 to 6.

	Certified Color Industry Report 1968[a]			Our 2014 Analyses	
Product	Serving Size	Parts Per Million	Range AFCs (mg)	Serving Size	Range AFCs (mg)
Beverages[1]	240 mL	5-200	1.2-48	240 mL	0.2-52.3
Candy and confections	15 g	10-400	0.15-6.0	11.9-61.5 g	0.3-33
Dessert powders	21.4 g	5-600	0.11-12.9	½ cup	1-12.2
Cereals	30 g	200-500	6-15	¾-1 cup (26-32 g)	9.4-41.3
Bakery goods	30-125 g	10-500	2.4-15	25-97 g	1.2-55.3
Ice cream and sherbets	66 g	10-200	0.66-13.2	½ c (60-86g)	1.9-6
Snack foods	30 g	25-500	0.75-15	28 g	2.8-14.4

Abbreviation: AFC, artificial food color.
[a]Source: Certified Color Industry Committee,[6] as presented in Marmion DM. *Handbook of U.S. Colorants*. New York, NY: John Wiley; 1991.

sales ($673.2 million) by *Business Week* in the United States (and the world) and contain 29.5 mg of AFCs (and 27 g of sugars) in a quarter-cup serving.[11] Twizzlers were ranked 13th, with sales of $158.1 million.[11] One serving of Strawberry Twizzlers contained 13.1 mg of Red #40 and 19 g of sugars. Another popular candy is Skittles, ranked 14th, with sales of $150.2 million.[11] One serving-size bag (61.5 g) contained 33.3 mg of AFCs and 46 g of sugar. Many other candies contained AFCs in lesser amounts than in these examples.

Early behavioral studies tested children with only 26 or 27 mg of mixed dyes and reported that few children were sensitive to the AFCs. The amount was chosen based on total dye production divided by the population.[12] For example, Williams et al[13] published a study of 26 children challenged with 26 mg of AFCs disguised in chocolate cookies. Only 3 children reacted. Williams et al commented, "It is relatively certain that the amount of artificial colors in a commercial food would be a fraction of the amount in the challenge cookies."[13(p816)] Clearly, the previously published article about AFCs in beverages[1] and the evidence presented here indicate that much larger doses of AFCs should have been used for the challenges. Later studies used larger amounts and reported a higher percentage of children reacting to dyes. For example, Swanson and Kinsbourne[14] reported that 17 of 20 children reacted to a challenge of 100 to 150 mg of an AFC mix as assessed by a learning task. Pollock and Warner[15] reported reactions to a 125-mg mix of AFCs in 8 of 19 children based on standard parents' rating scales.

In 2 British studies by Bateman et al[16] and McCann et al[17] that measured the amount of behavioral changes in a large population of children challenged with AFCs, the researchers used only 20 to 30 mg of AFCs (plus the preservative sodium benzoate) for the challenges. They reported that the AFCs (and/or the sodium benzoate) caused significant hyperactivity-type changes in children both with and without ADHD. The Bateman and McCann studies may have been even more revealing if larger doses of dyes had been used. Nevertheless, these 2 studies led the European Union to require that foods containing AFCs must carry a warning label that the product might cause hyperactivity and inattentive behavior in some children. In the United States, the FDA convened a panel to study the issue and concluded by a vote of 8 to 6 that there was not enough evidence to require similar labels in the United States. However, they also concluded that further research needed to be carried out, including a "robust intake estimate."[18]

In 2008, Schonwald, editor of *AAP Grand Rounds*, remarked about the Bateman study, "Thus, the overall findings of the study are clear and require that even we skeptics, who have long doubted parental claims of the effects of various foods on the behavior of their children, admit we might have been wrong."[19)] The 2013 *Diagnostic and Statistical Manual for Mental Disorders (DSM-V)* published by the American Psychiatric Association lists diagnostic criteria, prevalence, treatment, and possible causes of recognized mental disorders, including ADHD.[20] For the first time, the electronic manual states, "A minority of cases [of ADHD] may be related to reactions to aspects of diet." One of these aspects is AFCs, although children who reacted to artificial colors in the studies by Egger et al[10] and Carter et al[9] also reacted to at least 2 common natural foods such as milk, wheat, chocolate, and others.

Some food manufacturers in the United States are slowly switching from AFCs to natural colors as is being done by the European Union. Natural dyes include anthocyanins (grapes), betacyanins (beets), carmine (extracted from crushed cochineal insects), lycopene (tomatoes), annatto (*Bixa orellana* tree), saffron, turmeric, riboflavin, chlorophyll. and caramel.[21] As

Wrolstad and Culver pointed out, "An appealing feature of natural colorants is that many may provide health benefits."[21(p61)] However, using natural dyes can be problematic because they may deteriorate more rapidly under conditions like heat, acidity, light, and time. However, several cereals, candies, and other foods are colored using natural dyes. Some yogurts contain AFCs, but others are dyed with natural dyes. For example, Yoplait Red Raspberry Yogurt uses beet juice for color, Yoplait French Vanilla uses turmeric and annatto, and Yoplait Trix Strawberry Banana Bash uses vegetable juice, β-carotene, and turmeric. For the most part, cheeses, if dyed, use β-carotene or annatto. Kraft recently announced that natural colors would replace AFCs in 3 of their macaroni and cheese products specially designed and shaped to appeal to children, although the change will not affect their elbow macaroni and cheese. The fast-food chicken chain Chick-fil-A has announced it is removing corn syrup from its white buns and AFCs from its sauces, dressings, and chicken soup. In the United Kingdom, candies such as M&Ms and McDonald's strawberry shakes are naturally dyed.

Estimating the amounts of AFCs in beverages, foods, and candies that children consume is important for designing new challenge studies. The amount consumed could easily exceed 100 mg of AFCs depending on the child and his or her particular diet. For example, a child who consumes 2 cans of orange or red soda (90 mg AFCs), a bowl of Cap'n Crunch Oops All Berries cereal (41 mg), a couple of handfuls of M&Ms (29.5 mg), and a slice of red velvet cake (10 mg) with red icing (34.7 mg) could consume more than 200 mg of AFCs (and more than150 g of sugars). Future studies should consider these AFC amounts when designing intervention studies with AFCs to test the effects on behavior.

Another issue is whether or not sugars worsen behavior. The results of challenge studies with sucrose or glucose have been mixed, with most concluding that double-blind placebo-controlled sugar challenges did not affect behavior or cognition in children.[22-24] In 1995, Wolraich et al[25] published a meta-analysis of these studies concluding that sugar challenges did not cause behavior changes. Thus, the prevailing wisdom among experts dismisses sugar as a major cause of behavioral problems. However, Goldman et al[26] reported that a sucrose challenge caused significant differences in the behavior of young children, compared with placebo. Prinz et al[27] found a positive correlation between dietary intake of sugar and activity level in normal, healthy preschoolers and between sugar consumption and destructive, aggressive behavior in hyperactive preschoolers. In 2007, Benton et al[28] studied the effects of 3 different breakfasts with either a low, medium, or high glycemic index in normal, healthy children in school. When children received breakfasts with a low glycemic index, scores on memory, attention, and time spent on tasks were significantly better than scores after the medium- or high-glycemic-index breakfasts. The behavioral effects of high-fructose corn syrup, which is used ubiquitously in the American diet, have not been tested. High-fructose corn syrup is composed of 42% to 90% fructose and 10% to 58% glucose,[29] whereas sucrose contains 50% fructose and 50% glucose. Recent studies suggest that fructose is metabolized differently from sucrose or glucose and may play a role in nonalcoholic fatty liver disease, dyslipidemia, and metabolic syndrome.[30-33] Using BOLD functional MRIs, Purnell et al[34] have reported that brain cortical responses to infused glucose are the opposite of those seen after fructose infusion. Thus, it seems important to investigate the effects of changing the ratio of fructose to glucose.

Clinical Suggestions

Parents who wish to try an AFC-free diet should be encouraged to read ingredients lists on every food, candy, and beverage their children consume. AFCs can also be found in some toothpastes, mouthwashes, and both prescription and over-the-counter medications such as ibuprofen, acetaminophen, cough medicine, and children's vitamins. If Yellow #5 or any color with a number is in the ingredients list, the product should be avoided for an AFC-free diet as should products that list "color added" without specifying whether the color is from AFCs or natural dyes, such as Fiber One Chocolate RTE, Cheerios Multi Grain, and Hidden Valley Ranch Light. Parents may be surprised to learn that AFCs are sometimes added to white icings, marshmallows, and marshmallow sauce to make them look whiter. Pickles contain yellow and blue dye to make the product look greener. Red #40 is used to color some barbecue sauces and cherry pie fillings. Yellow dye may be added to baked goods to make them look like they contain eggs. Blue #2 Lake and Red #40 Lake are used to color blueberries in some blueberry muffin mixes like Martha White and Betty Crocker. Some commercially and restaurant baked breads are dyed to give the impression that they contain whole wheat. Parents can select foods colored with natural colors such as β-carotene (yellow, orange), annatto (yellow), turmeric (yellow), blueberry or grape (purple), and beet powder (red).However, it is rare but possible for a child to react to one of these, especially annatto.[35,36]

Choosing healthy foods is important for every child—fresh fruits and vegetables, whole-grain breads, whole-grain pasta and rice, uncolored whole grain and

Table 8. Recommendations for Added Sugar Intake for Children by International and National Agencies and Groups.

Agency or Group Making Recommendations	Recommended Limits of Added Sugars/d (Percentage of Total Calories)	Kilocalorie Intake/d	Grams of Added Sugars	Teaspoons of Added Sugars/d
American Heart Association[41]				
Children 4-6 years old	4.5-5	1200-1400	16	4
Children 9-13 years old	3.0-4.4	1600-1800	12-20	3-5
Children 14-18 years old	4.4-6.5	1800-2200	20-36	5-9
United States Department of Agriculture (USDA) Dietary Guidelines, 2005[42]	6-10	2000	30-50	7.5-12.5
World Health Organization 2003[42]	10	2000	50	12.5
Healthy People 2020[40]	10.8	2000	54	13.5
National Academy of Sciences Dietary Reference Intake[43]	25	2000	125	31

low-sugar RTE cereals, low- or no-fat milk and dairy products, eggs, nuts, seeds, beans, lean meats, chicken, and fatty cold water fish such as fresh tuna and salmon. RTE cereals that are AFC free and contain low sugar include Kix, Cheerios, Grape-Nuts, Shredded Wheat, Corn Flakes, Kashi GoLean, and others. Snacking trends are moving toward 3 snacks a day for many children, which provide more than 27% of daily calories.[37] The snacks include desserts, salty snacks, candy, RTE cereals, and fruit drinks and sweetened beverage.[37] Many of these are high in added sugars and AFCs. These foods should be replaced with more nutrient-dense foods such as fresh vegetables and fruits perhaps with a tasty dip, unprocessed nuts and seeds, plain yogurt with added fresh fruits, whole grain crackers with low-fat cheese or RTE whole grain, low-sugar cereals with low- or no-fat milk.

Beverages, foods, and sweets that contain AFCs usually contain lots of added sugars and are rarely nutrient dense. There are very few foods listed in Tables 1 to 5 that could be described as *nutritious*, except perhaps yogurt, puddings, and fortified cereals. However, Snack Pack Lemon Pudding contains Yellow #5, 18 g of sugar, and no milk. Nesquik and Shamrock Farms manufacture "strawberry" milks that use Red #40 or Red #3 but contain no strawberries. All children should avoid high-sugar diets because added sugars contribute to obesity, heart disease, diabetes,[38] and dental caries.[39] The sugar content of a food is listed in grams on the Nutrition Facts label under carbohydrates. There are roughly 4 g in a teaspoon of sugar. Different agencies or groups make quite different recommendations for sugar intake (see Table 8). According to Healthy People 2020 the current intake of added sugars is 15.7% of calories or 78.5 g of added sugars. They recommend that all Americans, including children, should consume no more than 54 g/2000 kcal of added sugars or 13.5 teaspoons/d.[40] The American Heart Association recommends that children 2 to 18 years old consume <9 or fewer teaspoons (36 g) of added sugars per day.[41] Tables 1 to 6 show that just 1 or 2 servings of many foods and sweets exceed that amount. Sweetened soda pop, fruit drinks, and sports drinks frequently contain both AFCs[1] and large amounts of sugar or high-fructose corn syrup—as much as 40 g in a 12 oz can.

If a special occasion, such as a birthday or holiday, occurs that would normally involve eating foods and beverages containing AFCs, parents can look for alternatives. For example, cake mixes and ice cream that do not contain AFCs can be purchased. There are dye-free white icings. Children can help parents dye white cake mixes and icing with juice from natural foods, such as blueberries, raspberry, or dark sweet cherries. Although 7-Up, Sprite, and Squirt are clear beverages and do not contain AFCs, low-fat or no-fat white or chocolate milk, natural fruit juice, and bottled flavored water are better options. White candies such as peppermint or spearmint are usually dye free. Some chewy-type candies contain AFCs, but Mott's Medley and Ocean Spray Fruit Flavored Snacks are made from real fruit and do not contain AFCs.

Conclusions

Artificial food dyes are found in many beverages, foods, and candies commonly consumed by children in the United States and around the world. They are rarely found in what could be described as *healthy* foods and often contain a large amount of added high-fructose corn syrup and sucrose. Although beverages account for much of the AFCs and high-fructose corn syrup consumed by children, foods and sweets may also

contribute considerable amounts, depending on the diet of a given child. As Arnold et al stated in 2013, "Until safety can be better determined, we suggest minimizing children's exposure to AFCs. With the current concerns about childhood obesity, there appears to be no need to make food look more attractive than its natural color."[5(p607)] Children's diets should be surveyed and the total amounts of AFCs calculated. This amount could then be used to test the effects of the AFCs on behavior and learning in children in the United States.

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